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## THE RELATION OF WIND TO BIRD MIGRATION.

C. C. TROWBRIDGE.

THE influence of meteorological conditions on the migration of birds has been studied by a number of observers. Among the important monographs on the subject is that of Prof. W. W. Cooke, "Bird Migration in the Mississippi Valley," in which it is shown clearly that migratory waves of birds accompany changes of temperature. The wind directions and velocities were recorded in the paper mentioned but the author did not regard the migratory movements to be due to the direct effect of the wind, which was considered merely as the chief cause of the temperature changes.

The same view is held by Dr. W. Stone in his "Birds of Eastern Pennsylvania and New Jersey," in which by a series of curves the fact is illustrated that migratory waves of birds follow closely changes of temperature.

The author of the present paper believes that the bird waves described by the above observers were largely due to the direct influence of favorable winds, and that the wind is a more important factor in bird migration than it is generally regarded.

That the subject has not received much attention is shown by the recent valuable review on bird migration by Dr. F. H. Knowlton in *Popular Science Monthly*.<sup>1</sup> In the paper referred to no mention of the relation of the wind to bird migration is made. In fact, the word "wind" is not used in the thirteen pages of the article.

In considering the relation of meteorology to bird migration, general as well as local atmospheric conditions must be studied, and it is important that the atmospheric conditions where the birds start on their migratory journeys be determined, if possible. Furthermore, the number of new arrivals

<sup>1</sup> Knowlton, Dr. F. H. The Journeys of Birds, *Pop. Sci. Mon.*, vol. ix, No. 4, p. 323.

recorded in any locality is not always a safe criterion of the migratory movement of birds, because adverse meteorological conditions often tend to retard or stop the migrations and bring certain species under notice which, with favorable conditions, would have passed by unobserved.

A previous paper by the author, "Hawk Flights in Connecticut,"<sup>1</sup> contained an account of flights of hawks which had occurred along the southern border of Connecticut during the autumn migrations, in which the results were presented of observations covering a period of nine years, from 1885 to 1894.

The present paper is an account of further observations on the migrations of hawks and on the effect of the wind on the migrations of various other species of birds. It is necessary to refer to the contents of the previous paper on the subject, and the principal facts given in it are as follows :

It was shown that flights of hawks occurred in September of almost every year in southern Connecticut, consisting of different species, some of which passed along the coast singly, others in flocks of from twenty to two hundred. The hawks were most numerous at from one half to one mile inland from Long Island Sound, along the first low hills back from the coast.

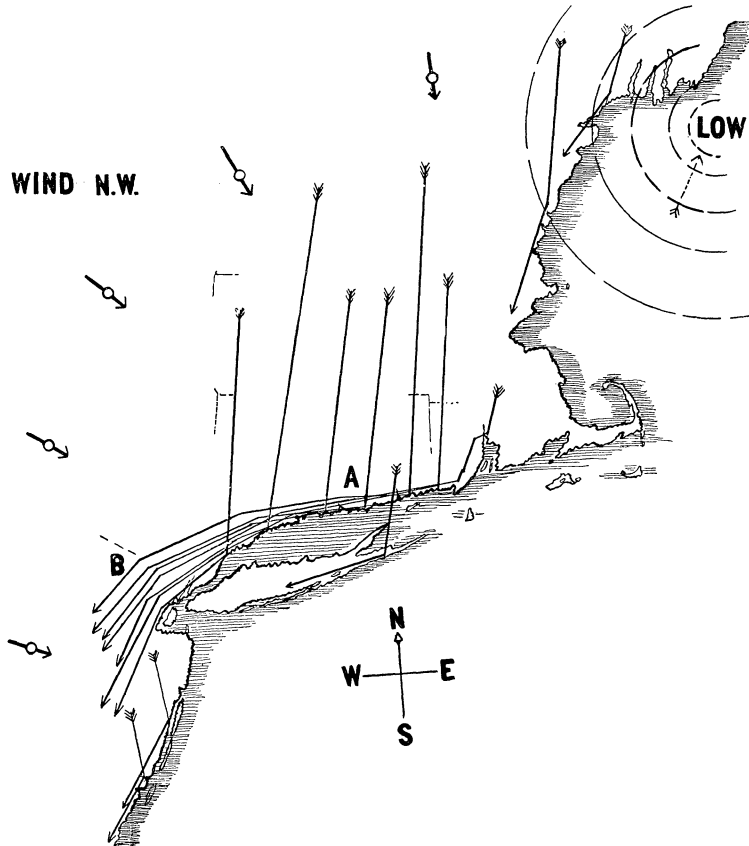
Twenty-two hawk flights were recorded in nine years, and in each case notes were made on the relative abundance of the different species of hawks seen migrating. A record was kept of the meteorological conditions on the days when the flights in question took place. It was found that on the days when the flights occurred the wind blew from the north or northwest, and usually with considerable velocity. On seven days the wind blew at the rate of over twenty miles an hour, and on eight other days not less than fifteen miles. The greatest flights occurred on three days, when the velocity of the wind was about forty miles per hour during part of the day.

An explanation of the cause of these autumn flights of hawks was given, and the theory advanced has been fully verified by

<sup>1</sup> *The Auk*, July, 1895.

subsequent observations. The cause of the flights was stated to be as follows :

Hawks drift with the wind when soaring, and as they soar continually, their movements during migrations are largely dependent on the direction of the wind. In the present case hawks migrating in autumn in New England drift south or



MAP I. — COAST LINE OF THE NEW ENGLAND STATES AND NEW JERSEY.

The long arrows indicate the general direction of migration of hawks and many other land birds in the autumn, when the wind is northwest, illustrating why these birds congregate at the coast line of Connecticut.

The broken circles drawn about a point off the coast of Maine are low-pressure isobars indicating a storm center traveling northeast and causing the northwest winds over the northeastern part of the United States. At the point *A* the hawks follow a narrow path and fly low ; at *B* the hawks gradually separate, usually flying higher as the wind becomes more favorable.

southeast until they reach the Atlantic coast line. They then turn westward and follow the shore until they have reached New York and New Jersey, where they gradually separate and pass on southward. Thus the hawks migrating from a large area of country — eastern Canada, New England, and perhaps north-eastern New York — are forced to travel along a narrow coast-line path at right angles to the main direction of their migration.

A condensed table of flights which occurred from 1885 to 1895 is given below. It has already been published in part, but it is necessary in the present paper for the purpose of showing certain new facts that will be presented.

The meteorological data in the table as formerly given was that for New Haven, Conn., where the observations on hawk flights were made. In the table as given at present the observations of the U. S. Weather Bureau taken at Boston are substituted for those taken at New Haven. This change is made because the former station is nearer the locality where the hawks start on their migratory journey than the latter place. Another column has been added to the table for the purpose of showing the effect of temperature changes on the migratory movements of the hawks. The meteorological data in the tables have been kindly furnished by the Boston office of the U. S. Weather Bureau.

It is difficult to determine the number of hawks that pass a given point on the Connecticut shore, during a moderately large flight in September. An estimate, which appears to the author to be conservative, is that over 15,000 of them pass New Haven in one day. The sharp-shinned hawks outnumber the other species several times over. The broad-winged hawks are next in abundance, then the ospreys and marsh hawks which are about equally numerous.

Observations show that many ospreys and marsh hawks cross to Long Island, but it is evident that the main flight of hawks is along the Connecticut shore.

Since 1894 observations have been continued on flights of hawks in Connecticut in autumn, and in New Jersey in spring, which have resulted in bringing to light additional facts relating to the effect of wind on the migration of birds.

TABLE I.<sup>1</sup>

LIST OF MIGRATORY FLIGHTS OF HAWKS WHICH HAVE OCCURRED IN  
SOUTHERN CONNECTICUT DURING THE YEARS 1885-95.  
METEOROLOGICAL RECORDS, BOSTON, MASS.

DATE.	WEATHER.	WIND DIREC- TION.	WIND VELO- CITY; MILES PER HOUR.	TEMPER- ATURE CHANGE IN PAST 24 HOURS	REMARKS.
Sept. 23, '85	Rain	N.W.	14	- 7	Moderate flight; <i>Falco spar- verius</i> common.
Sept. 18, '86	Clear	N.W.	21	- 8	A great flight of small hawks and various other land birds.
Sept. 22, '86	Partly cloudy	N.W.	10	- 2	<i>Buteo latissimus</i> abundant.
Sept. 16, '87	Clear	N.	12	- 5	A great flight all day.
Sept. 17, '87	Clear	N.W.	8	- 7	<i>Buteo latissimus</i> abundant early in the morning.
Sept. 24, '87	Clear	N.	14	- 10	<i>Buteo latissimus</i> abundant, also <i>Accipiter velox</i> .
Oct. 19, '87	Cloudy	N.	10	- 11	No large flight, but almost all the migrant hawks observed.
Sept. 10, '88	Cloudy	W.	9	- 2	<i>Accipiter velox</i> abundant.
Sept. 22, '88	Cloudy	N.	24	- 3	Moderate flight.
Sept. 22, '89	Clear	W.	14	- 8	
Sept. 28, '89	Clear	W.	14	- 5	Very large flight.
Oct. 15, '89	Clear	N.	19	+ 5	Moderate flight; <i>Accipiter velox</i> plentiful.
Sept. 18, '90	Cloudy	W.	13	- 2	40 hawks killed; <i>Buteo latissi- mus</i> abundant.
Sept. 21, '90	Clear	N.W.	14	- 16	Moderate flight.
Sept. 23, '90	Clear	W.	14	+ 2	<i>Pandion halietus carolinensis</i> abundant.
Sept. 24, '90	Clear	N.W.	20	- 8	Small flight.
Sept. 8, '91	Clear	W.	11	- 2	Hawks increasing in numbers.
Sept. 9, '91	Clear	W.	10	- 5	A large flight; killed over 20 hawks.
Sept. 14, '91	Clear	W.	11	+ 2	Small flight.
Oct. 21, '92	Cloudy	W.	9	- 3	Small flight of <i>Accipiter velox</i> .
Sept. 20, '93	Clear	W.	8	+ 1	Large flight; <i>Buteo latissimus</i> abundant.
Sept. 21, '93	Clear	N.W.	12	- 12	Great flights of adult <i>Buteo latis- simus</i> .
Sept. 13, '95	Cloudy	N.	14	- 10	Large flight.
Sept. 14, '95	Clear	N.W.	14	- 11	Great flight of <i>Buteo latissimus</i> .

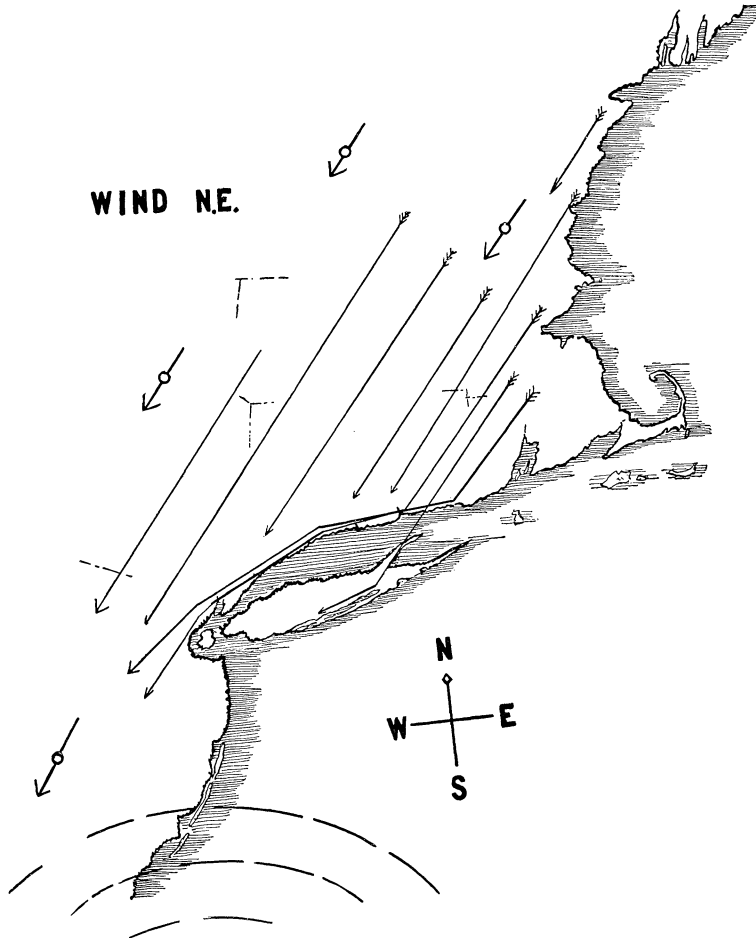
<sup>1</sup> The flights of hawks recorded in the above table were observed at New Haven, Conn., and the meteorological data given is that for Boston, from 1885 to 1887 at 7 A.M., from 1888 to 1895 at 8 A.M. The reason for giving the meteorological conditions for Boston has been already explained.

During September, 1895, daily observations were made on the migration of hawks at New Haven, Conn., when as far as possible the variety, as well as the number of hawks which were seen on each day, was noted. A record was also kept of the meteorological conditions for the same period, particularly the state of the weather and the velocity and direction of the wind.

The observations extended over a period of twenty-three consecutive days, from September 6 to September 29, this being the month during which five or six species of hawks migrate southward. The object of these observations was to ascertain if wind from a southerly quarter not only retarded the migration, but practically stopped it, and also to determine if the migratory movement ceased when there was little or no wind. The observations were as follows :

- Sept. 6. Fair ; wind N.E., 11 miles. 1 bald eagle ; 1 fishhawk ; 2 sharp-shinned hawks.
- Sept. 7. Fair ; wind N.E., 16 miles. 1 broad-winged hawk.
- Sept. 8. Cloudy ; wind S.W., light. 1 sharp-shinned hawk.
- Sept. 9. Cloudy ; wind S., light. 1 large hawk ; 1 sparrow hawk.
- Sept. 10. Warm and hazy ; wind S., very light. No hawks seen.
- Sept. 11. Cloudy ; wind S.W., 10 miles. 1 fishhawk ; 1 sparrow hawk ; 3 sharp-shinned hawks.
- Sept. 12. Fair ; wind S.W., light. No hawks seen.
- Sept. 13. Clear, cool ; wind N.N.W., 22 miles. Several flocks of broad-winged hawks of from ten to fifteen observed ; 4 adult bald eagles ; hundreds of sharp-shinned hawks, and fish, sparrow, and marsh hawks common.
- Sept. 14. Clear, cool ; wind N. by W., fresh. All the hawks which were observed yesterday, common to-day. A number of eagles also seen. Broad-winged hawks exceedingly abundant ; flock after flock passed westward over New Haven, Conn. Eighty-five were counted in one flock, while another equally large body of them was observed at the same time. These hawks passed over the city continually from 7 A.M. until 3 P.M.
- Sept. 15. Clear, cool ; wind N., light. A few hawks observed migrating at a high altitude.
- Sept. 16. Cloudy ; wind N. to S.W., light. No hawks seen.
- Sept. 17. Clear ; wind S., 5 miles. 2 fishhawks ; 1 sharp-shinned hawk.
- Sept. 18. Light rain ; wind N.E. No hawks seen.
- Sept. 19. Light rain ; wind S., light. 1 fishhawk.
- Sept. 20. Cloudy ; wind S.W., light. No hawks seen.

- Sept. 21. Clear, warm; wind W. No hawks seen.  
 Sept. 22. Clear; wind N.W., light. A few sharp-shinned hawks.  
 Sept. 23. Wind W. by N., light. No hawks seen.  
 Sept. 24. Cloudy; wind N., 12 miles. A small number of broad-winged and sharp-shinned hawks and one each of the following species: fish, marsh, and sparrow hawks.  
 Sept. 25. Stormy; wind S.E., light. No hawks seen.



MAP II. — COAST LINE OF THE NEW ENGLAND STATES AND NEW JERSEY.

In this case the long arrows indicate the direction of migration of hawks in the autumn when the wind is northeast. A storm center is indicated by low-pressure isobars south of the New Jersey coast, causing northeast winds in New England. When the wind is northeast there is usually a small flight of hawks along the Connecticut shore, as indicated.



- Sept. 26. Fair; wind S.W., 10 miles. 2 fishhawks; 1 sparrow hawk.  
 Sept. 27. Cloudy; variable light winds. No hawks seen.  
 Sept. 28. Clear; variable light winds S.E. 1 fishhawk.  
 Sept. 29. Stormy; wind E. 1 fishhawk.

In the table given below are placed the days, thirteen in number, taken from the above list, when not more than one hawk was seen. The meteorological conditions at New Haven on these days is also recorded in the table. An inspection of the observations shows that no strong northwest winds occurred on any of these days.

TABLE II.

DATE, 1895.	WEATHER.	WIND DIRECTION, LOWER STRATA.	WIND VELOCITY, MILES PER HOUR.	NUMBER OF HAWKS OBSERVED.	DIRECTION OF UPPER STRATA.
Sept. 7	Fair	N.E.	15	1	—
" 8	Cloudy	S.W.	18	1	—
" 10	Fair	Variable	—	0	—
" 12	Fair	S.W.	7	0	—
" 16	Cloudy	S.W.	7	0	—
" 19	Rain	N.E.	6	1	N.E.
" 20	Cloudy	S.W.	5	0	W.
" 21	Clear	W.	2	0	—
" 23	—	W.	1	0	W.
" 25	Cloudy	E.	Light	0	N.
" 27	Cloudy	N.	4	0	—
" 28	Clear	N.	9	1	—
" 29	Cloudy	N.E.	7	1	S. by W.

It has been observed that the direction of the movement of the upper strata does not influence the migratory movement, and that the surface currents are those in which the hawks usually migrate. In the last column of Table II the direction in which the upper strata were moving is given in a few cases. The table, of course, is not meant to show the number of birds migrating, but it gives an idea of the number of hawks observed by one constantly watching for them.

In the table given below, the U. S. Weather Bureau observations are those for Boston on the days given in Table II. It is evident from a comparison of these two tables (II and

III) that the meteorological conditions on nearly all days were very unsettled in New England, and that although in a few cases the wind direction, for a time at least, was favorable for a migration of hawks near Boston, the adverse conditions in Connecticut stopped the migratory movement.

TABLE III.

UNITED STATES WEATHER BUREAU OBSERVATIONS AT  
BOSTON, MASS., 8 A.M., SEPTEMBER, 1895.

DATE, 1895.	WEATHER.	WIND DIRECTION.	WIND VELOCITY, MILES PER HOUR.	TEMPERATURE CHANGE IN PAST 24 HOURS.
Sept. 7	Cloudy.	N.	13	+3
" 8	Cloudy.	N.W.	14	-1
" 10	Cloudy.	N.W.	3	+1
" 12	Cloudy.	N.W.	5	-2
" 16	Cloudy.	S.W.	12	+3
" 19	Cloudy.	N.	8	+4
" 20	Partly cloudy.	W.	12	+6
" 21	Clear.	N.	2	-1
" 23	Clear.	W.	7	+2
" 25	Clear.	N.	3	-2
" 27	Cloudy.	W.	12	-3
" 28	Clear.	N.	7	-10
" 29	Clear.	E.	18	+2

In Table II, as well as in Table III, the directions and velocities of the winds were taken from the local U. S. Weather Bureau records.

There is a slight discrepancy between some of these observations and those taken by the author and given previous to Table II. These differences are due to variations in the direction of the wind on certain days. For example, part of the morning of September 28, Table II, the wind direction was S.E. and light, while at the time of the U. S. Bureau observation it was N., 9 miles. The table on the following page shows the days of September, 1895, when flights of hawks occurred.

TABLE IV.

DATE, 1895.	WEATHER (New Haven).	WIND DIRECTION (N.H.).	WIND VELOCITY (N.H.).	NUMBER OF HAWKS OBSERVED.
Sept. 13	Clear.	N.N.W.	22	Large flight.
" 14 <sup>1</sup>	Clear.	N.W. to N.	9	Very large flight.
" 15	Clear.	N.	13	Small flight.
" 24	Cloudy.	N.	12	" "

The observations made of flights of hawks that have occurred during a period of fifteen years show that they have taken place on nearly every date during September, after the 5th of that month. This is readily seen from Table I, which gives the flights of hawks which occurred during the years 1885 to 1895. It is evident that there is no special date on which the hawks migrate during the month of September. Their appearance in large numbers must be due therefore to some special influence. This has already been shown to be the wind from the north-west quarter, in which the birds drift southeastward to the coast line, making necessary their flight along the shore of Connecticut.

The observations made during September, 1895, show an additional fact; if hawks migrated regularly in New England throughout September without regard to the direction of the wind, then there would be a small continual flight of hawks in southern Connecticut during the entire month, due to the peculiar shape of the coast line. Such would be the case, because hawks migrating in a southward direction through the New England States would eventually reach the southern border of Connecticut, where it would be necessary for them to fly westward along the coast, producing the small daily flights referred to.

It has been proved that no daily flight takes place, only a few stray hawks being observed. Moreover, at any time

<sup>1</sup> In Table IV the velocity of the wind at 8 A.M., September 14, is given as 9 miles at New Haven. At Boston, however, at the same time the wind was N.W. 14 miles, and at New York 12 miles.

On September 24 the wind at Boston was N. 18 miles, and at New York N.W. 14 miles.

during the month a flight of many thousands of hawks will occur if the wind turns to the northwest quarter, the hawks appearing within several hours after the change of the wind takes place. This is shown by the following example :

The morning of September 18, 1890, was warm and calm. In the most favorable station for observations near New Haven, between sunrise and nearly eight o'clock, only two hawks were observed. About eight o'clock a breeze started up from the northwest, and a great number of hawks soon appeared, over forty of which were shot. Again, on September 12 and 23, 1895, no hawks were seen, but on the dates immediately following, September 13 and 24 respectively, hawks appeared in large numbers.

The significance of these facts is that the wind not only changes the line of flight of the migrating hawks, but that it is also the immediate cause of their migratory movement.

In further proof of this statement it has been observed that when a northwest wind blows for three days in September, on the third day hawks are not abundant ; for all of those hawks which are ready to fly southward start at once when the wind begins to blow in a favorable direction.

A second wind from the northwest quarter, after a week of southerly winds or calm, will produce a second flight of hawks, usually of shorter duration than the first.

A third favorable wind will seldom cause another large September hawk flight, although every wind from the north or northwest throughout the autumn produces a greater or less abundance of hawks along the Connecticut coast.

The expression "the immediate cause of migratory movement," used in the present paper, perhaps requires an explanation : If a favorable wind, acting as a physical agent, is used by birds as a means of migration, it is also an immediate cause of their migratory movement because it determines the time of their migration.

By the expression "favorable wind" is meant a wind which when resolved into components with respect to the migratory direction shows one favorable to the migration.

EFFECT OF TEMPERATURE CHANGES ON THE MIGRATORY  
MOVEMENTS OF HAWKS.

To what extent these flights of hawks and other land birds are due to changes of temperature is difficult to determine. An examination of the data given in Table I, however, shows the following facts:

1. The direction of the wind at Boston at the 7 and 8 A.M. observations on days when twenty-four flights of hawks occurred was as follows: north, six days; north-west, eight days; west, ten days. Total, twenty-four days.

2. The mean velocity of the wind for the twenty-four days (morning observations) was thirteen miles an hour, maximum twenty-four miles per hour, minimum eight. (In many cases the wind increased considerably during the day.)

3. Mean change of temperature in past twenty-four hours of twenty-four days on which flights occurred was  $-5.7$  degrees.

4. The number of days with higher temperature than the preceding day was four ( $+5 + 2 + 2 + 1$ ).

5. The number of days with lower temperature than preceding day, but less than three degrees change, was six ( $-2 - 2 - 3 - 2 - 2 - 3$ ).

From the above it is seen that on ten days of the twenty-four in the table the temperature was either higher than the preceding day (in four cases) or lower by not more than three degrees. It seems evident, therefore, that the chief causes of the great migratory movements that occurred on the days given in the table were the favorable winds and not diminution of temperature.

## TIME OF DAY DURING WHICH HAWKS MIGRATE.

When hawks occur in flights during the autumn migrations they usually make their appearance some time after sunrise and continue flying all day, the maximum of the flight occurring in the forenoon in southeastern Connecticut and in the afternoon near the New York state line. In the former locality the sharp-shinned hawks begin to appear soon after sunrise and

the broad-winged hawks usually not until about eight o'clock, unless there has been a favorable wind the previous day, in which case the flight begins earlier. Many other species of birds, — woodpeckers, thrushes, blackbirds, etc., — apparently acting under the same influence that produces the migration of hawks, namely, the favorable winds, make their appearance before sunrise near the Connecticut shore and are abundant for a few hours only, because they soon fly back into the country to feed. The birds mentioned are known to migrate at night. Most species of hawks, on the contrary, appear to migrate during daylight only. This point is in agreement with observations made by others.

#### THE MIGRATION OF THE BROAD-WINGED HAWK.

The behavior of the broad-winged hawks when they are migrating in flocks is peculiar. If, for example, these birds are soaring together in a flock of from twenty-five to fifty, one bird will be seen to separate from the flock, set its wings, and sail away in the migration direction (west in southern Connecticut). Presently another will follow at an interval of a few hundred feet; then another, until finally the entire flock is observed to be sailing with set wings in single file. When the hawks have sailed from a half mile to two miles this way, they collect together and begin to soar again in an area of about one or two acres and continue circling until they have attained a considerable height. The peculiar manœuver is then repeated.

The broad-winged hawk is the only one of the entire family that shows a decided tendency to collect in large flocks during the migration. Red-tailed hawks are sometimes observed in small flocks.

#### HAWKS BLOWN OUT TO SEA.

Strong northwest winds are undoubtedly the cause of many birds being blown out over the Atlantic Ocean and lost during the southward migration. Hawks form no exceptions, for instances like the following are not unfrequently reported:

When the Munson line steamship *Curitiba*, bound for New York, reached lat.  $30^{\circ}$  N., long.  $70^{\circ} 30'$  W., on Oct. 11, 1900, "five ospreys came on board; two of them were shot, one was captured, one alighted on the after-deck boat and then fell into the sea, and the remaining one fell down the funnel. At dusk on the following day two more hawks were captured." These facts were given to the author of this paper by Captain Hoppe of the *Curitiba*.

When the birds were first seen the *Curitiba* was 500 miles from Florida and 400 miles from Cape Hatteras. According to the U. S. Weather Bureau observations taken at 8 A.M. on October 10, at Cape Hatteras, the wind was north, 28 miles per hour, and on October 11, north, 14 miles per hour. At Boston, on October 11, the wind was northwest, 24 miles per hour.

These strong offshore winds were unquestionably the cause of the appearance of the hawks far out at sea. The *Curitiba* also encountered a large number of bats which had evidently blown out to sea by the northwest wind.

#### MIGRATING PERIODS OF VARIOUS SPECIES OF HAWKS IN AUTUMN.

In the table on the opposite page the periods when a number of species of hawks migrate southward in the latitude of Connecticut are given.

#### WIDESPREAD EFFECT OF STORMS.

It is well known that high north and northwest winds are directly due to centers of low barometric pressure lying to the eastward.

In the northern hemisphere the motions of the lower strata of the atmosphere about centers of low barometric pressure are counter-clockwise. These low areas are known as storm centers, and in the eastern part of the United States they usually travel in a northeasterly direction. A storm of moderate intensity is shown by Map III, which is an approximate representation of the U. S. Weather Bureau map of

TABLE V.

SPECIES.	DATE.	ABUNDANCE.
Fishhawk ( <i>Pandion haliaetus carolinensis</i> )	Sept. 1-Oct. 15	Abundant.
Marsh hawk ( <i>Circus hudsonius</i> )	Sept. 1-Oct. 10	Very common.
Pigeon hawk ( <i>Falco columbarius</i> )	Sept. 10-Oct. 10	Regular, but not common.
Sparrow hawk ( <i>Falco sparverius</i> )	Sept. 10-Oct. 10	Very common.
Sharp-shinned hawk ( <i>Accipiter velox</i> )	Sept. 5-Oct. 15	Very abundant.
Cooper's hawk ( <i>Accipiter cooperi</i> )	Sept. 5-Oct. 15	Very common.
Goshawk ( <i>Accipiter atricapillus</i> )	Oct. 25-Nov. 25	Occasional, sometimes common in November.
Broad-winged hawk ( <i>Buteo latissimus</i> )	Sept. 10-Oct. 1	Very abundant.
Red-shouldered hawk ( <i>Buteo lineatus</i> )	Oct., Nov. (?)	Common.
Red-tailed hawk ( <i>Buteo borealis</i> )	Oct. 20-Dec. 1	Very common.

September 18, 1900. The map shows the extent of country throughout which north or northwest winds prevailed at 8 A.M. on that date. These winds were reported throughout an area of over 800,000 square miles, and their recorded velocity varied from ten to forty miles per hour.

Owing to these winds a large southward flight of birds must have occurred on the given date in eastern Canada and in the eastern part of the United States.

This map is employed to show also the general migration directions of various water birds in the eastern part of the United States. The arrows *AA* show the probable line of flight of many ducks, swans, and shore birds from the interior of Canada to the North Carolina coast. Those marked *C* show the sea flight of many water birds from Labrador, as noted in the Gulf of St. Lawrence region by the author, and those marked *B* indicate the direction of the coast line migration.



The converging arrows *AA* and *C* explain the abundance of water fowl along the coast of North Carolina.

#### FLIGHTS OF HAWKS IN SPRING.

From the middle of March until the first part of May flights of hawks occur along the Atlantic coast. These flights appear to be greatest over the hills near the New Jersey coast, but occur also at some distance in the interior. Near Paterson there is a hill about 500 feet high, part of the Watchung range, over which large numbers of hawks pass in the spring. On the west slope of this hill many pits and brushwood blinds are made every year, both in the woods and in the open ground, and are occupied during March and April by men and boys who make a practice of killing hawks for New York and New Jersey taxidermists. The author has witnessed several flights of hawks on this hill, which is the first high land back of the coast.

The most favorable wind for a flight is west, or a little south of west. The red-tailed hawks are the first to appear in the spring, and the sharp-shinned and the broad-winged hawks are the last. The periods when some of the hawks may be expected are given below :

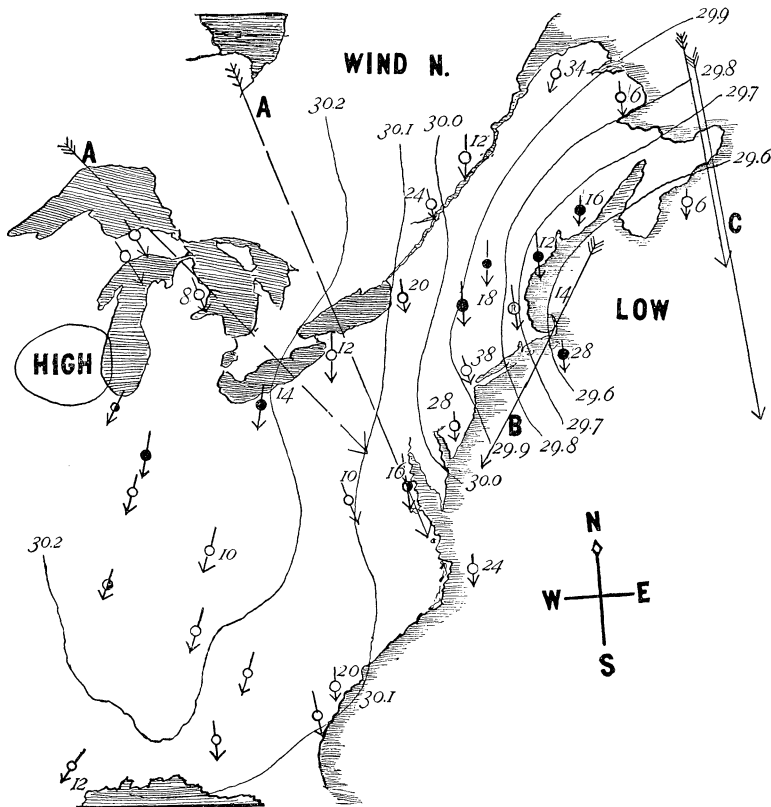
Fishhawk, latter part March to May 1.  
Marsh hawk, April.  
Sharp-shinned hawk, April 10–May 10.  
Cooper's hawk, April.  
Broad-winged hawk, April 10–May 5.  
Red-tailed hawk, March 1–April 10.

Observations described above seem to warrant the following conclusions :

1. That the migratory movements of hawks are largely determined by the direction of the wind, hawks regularly depending on favorable winds as a help in migration.
2. That an adverse wind not only retards the migratory movement, but that it almost completely arrests it.
3. That the migratory period of the various species of hawks lasts for from about fifteen days to one month ; during this time the migratory movements take place on days when favorable winds occur.

4. When the wind is favorable and approximately parallel to the direction of migration, hawks fly and sail at a high altitude and occasionally soar in circles.

5. When the wind is favorable but nearly perpendicular to the migratory direction (the favorable component being small),



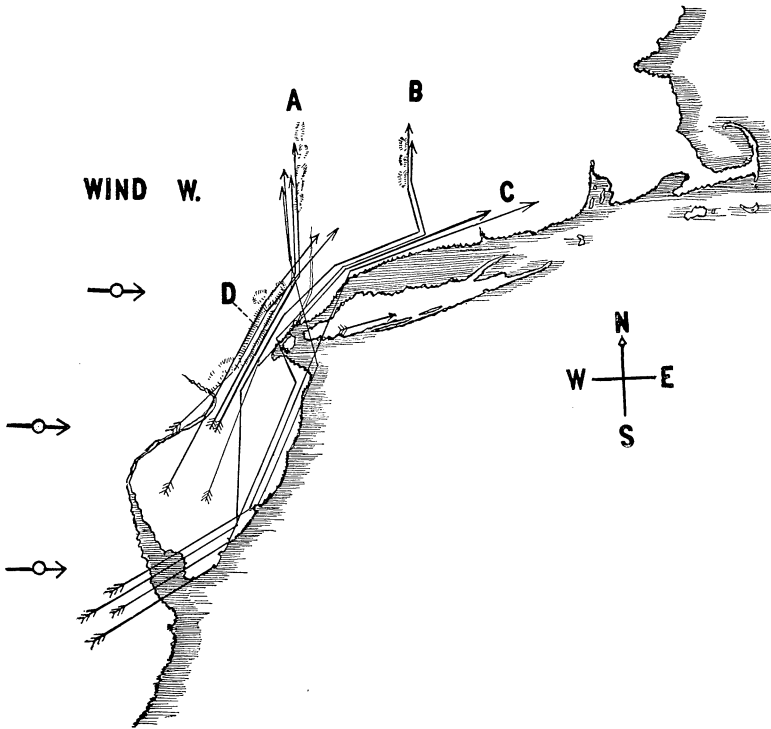
MAP III.—EASTERN CANADA AND EASTERN UNITED STATES.

The dotted lines are the isobars of September 18, 1900. A low barometric pressure is centered off the Maine coast. The small arrows indicate the direction of the wind, and its velocity in miles per hour is given in a number of cases. The mean velocity of the wind records on the map as it is given here is over seventeen miles per hour.

hawks fly low and soar continually, often alternating soaring with the wind and flying or sailing nearly against it.

6. That hawks migrate during the daylight, and, other conditions being the same, they are most abundant in migratory flights when the atmosphere is clear.

7. When a migratory flight of hawks takes place, continued favorable winds exhaust the number of hawks ready to make the migratory journey, but a second favorable wind about one week later may cause a second flight equal in magnitude to the first.



MAP IV. — COAST LINE OF SOUTHERN NEW ENGLAND, NEW JERSEY, AND DELAWARE.

The long arrows indicate the direction of migration of hawks and various other birds in the spring, when the wind is west or southwest. Owing to the fact that the coast line is nowhere at right angles to the direction of migration, the flight is not in a narrow path, as along the Connecticut shore in autumn, but ten or fifteen miles wide in the northern part of New Jersey.

The arrows marked *A* show a flight up the Hudson valley, those marked *B* a flight up the Housatonic valley in Connecticut, and those marked *C* a general northeast flight in New England. The Watchung range, along which many hawks migrate, is indicated by *D*.

8. That a favorable wind, when the favorable component is small, may cause decided deviations of the course of the migrating birds from the main migratory direction.

These conclusions apply to both the northward and southward migrations. Most of the effects of the winds stated are intensified when the wind is strong.

It has been observed that after a period of adverse or light winds, during which no migratory movement was noticed, a moderate wind in a direction favorable to the migration causes a marked migratory movement, especially if such a wind is general and not local. It thus seems evident that birds wait for a favorable wind to carry them on their migrations.

Changes of temperature, without doubt, affect the migratory movements of hawks, but, as has already been shown, a number of large flights have occurred in autumn on days when rises of temperature occurred near where the hawks started on their journeys. Moreover, flights of hawks often occur on cool days in spring, lower temperature usually accompanying west winds at that season of the year.

Water birds, particularly the *Limicolæ*, migrate in large numbers from the north in July, before the hottest period of the summer has passed. It is not surprising, therefore, to find causes affecting the time of migration of birds other than changes of temperature.

It is probable that many varieties of birds regularly make use of the wind as a physical agent in carrying them on their migratory journeys, the habit being well formed in the case of the *Falconidæ*.